CEMENT

AND

CEMENT MANUFACTURE

A MONTHLY JOURNAL FOR ALL INTERESTED IN THE MANUFACTURE, CHEMISTRY & TESTING OF CEMENT

VOL. I. No. 3.

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Fundamentals of Portland Cement Manufacture.

SOME DEBATABLE POINTS.

THE cement manufacturer has two principal objects in view, viz. to make good cement and to make it cheaply. There are so many different means of attaining these ends that the student of the subject is at first inclined to think that the technique of cement manufacture is in a chaotic condition because of the various answers that different experts may give to the same question. A further study of the manufacture will, however, reveal that the emphasis laid upon the importance of one particular feature allows of laxity in another direction, and weakness in one department of the manufacture is compensated by greater care in another of the manufacturing operations. There is, in fact, not a straight and narrow road to the production of a cheap and good cement, but a number of avenues leading to the same destination. Nevertheless it is not to be supposed that the quality of Portland cement has reached its climax, nor has the cost of production reached its minimum, so that the factors tending to high quality and low cost need to be kept continually in view by the manufacturer.

Lime Content.

The quality of cement is a matter of chemistry, and it is obvious that the manufacturer should aim at the production of certain chemical compounds. But in spite of the large amount of research work that has been done upon the subject there is no unanimity of opinion as to the compounds present in a good cement. There are some chemists who think that tri-calcium silicate and tri-calcium aluminate are the best cement-making compounds, and that cement containing these constituents only would be the ideal; but other chemists assert that tri-calcium silicate does not exist in cement, and it is therefore futile to aim at its production.

The difficulties of isolating the various compounds in cement are so great that it is unwise to be dogmatic in the matter, and to some extent there must be an empirical basis for the manufacture. It is, however, a matter of agreement that the nearer the composition approaches to the proportions required for tri-calcium aluminate and tri-calcium silicate (or, more crudely, the more lime a cement contains up to the limit within which it remains sound to a boiling water

test) the greater will be its strength, and this is a sufficient guide for the manufacturer in the present state of knowledge.

Silica and Quality.

The proportions of the other main constituents of cement, viz. silica, alumina, and iron oxide, can vary within wide limits without any apparent effect upon quality. A scrutiny of the chemical analysis of a large number of cements, and especially those of the highest quality (rapid-hardening cements), shows that there is no relation between the silica-alumina ratio and quality; in fact, a German research worker has gone so far as to say that high silica content as well as high alumina content in cement tend to good quality, while cements with medium proportions of silica and alumina are handicapped by such a composition.

Certainly the idea that high silica cements are inevitably slow-hardening is no longer tenable. A writer from a Mexican works has recently produced evidence to show that an increase in the iron oxide content of a cement improves its quality, but whether this is because of its fluxing action or its chemical effect is not known.

From a chemical standpoint, therefore, the cement manufacturer has a large margin in the range of raw materials that can be used, and apart from the physical characteristics of these there is not much to choose between one material and another.

Burning and Grinding.

The chemical process in cement manufacture is the conversion of a mechanical mixture, say of chalk and clay, to a chemical compound or compounds by the application of heat. If the heating could be taken to the fusing point the process would be simplified because of the greater homogeneity and efficiency of chemical reaction that results in a liquid. But as fusion of Portland cement is not commercially practicable, the necessary chemical interaction between the cement materials must be encouraged by one or both of two means, i.e. by fine grinding and thorough mixing of the raw materials and by hard burning to get as near fusion as possible.

This introduces some of the questions that are perennially discussed: first, whether the dry process of manufacture can ever reach the degree of perfection of mixing raw materials that is admittedly possible with the wet process; second, whether it is more advantageous to grind the raw materials finely and endeavour to recoup the cost of so doing by burning lightly, or alternatively to grind coarsely the raw materials and compensate the quality by hard burning; third, whether the benefit to chemical reaction obtained from hard burning is lost in the difficulty of grinding the clinker to the necessary flour standard. Each of these questions needs to be separately discussed in the light of evidence regarding power consumption in the mills and fuel consumption in the kilns.

As to the final stage in cement manufacture, viz. the clinker grinding process and its effect upon quality, there is only one opinion to be held, viz. the finer the better. But the methods of obtaining the necessary degree of fineness again form a subject for discussion in which the respective merits of two-stage grindinig compound mills, pendulum mills, and air separation require to be considered in regard to their ability to produce cement with the greatest proportion of flour.

Cost of Production.

Turning to the factors in cement manufacture which influence the cost of production, the first great controversy is the wet versus the dry process. The arguments on both sides are numerous, and they introduce subsidiary questions such as the effect on quality (already referred to), the value of waste-heat boilers in both wet and dry processes of manufacture, whether effective dust-collection from kilns is economically possible, etc.

The discussions as to the type of kiln to be favoured are becoming less intense, and except under very unusual conditions no other but the rotary kiln would be recommended for modern conditions which demand high quality, minimum employment of labour, and large manufacturing units. But the best dimensions for rotary kilns remains a subject upon which many different opinions could be cited, each with a basis of sound experience. There is, moreover, a greater prospect of economy in the rotary kiln operation than in the other departments of manufacture, and it is naturally a matter of prime interest until the necessary evidence is available to decide the net advantages of the short kiln, the long kiln, the kiln with the enlarged burning zone, the enlarged calcining zone, or the enlarged slurry zone.

The type of coal to be used in rotary kilns is frequently settled by considerations of price, but in some cases there is a choice between coal with a high volatile content and a low volatile content, or between low-priced coal with much ash and an expensive coal of high calorific value; there are advocates for each of these alternatives. The degree of fineness of coal grinding is bound up with the quality of coal, and in its turn introduces the question of the best type of mill for the purpose—the unit pulveriser, the tube mill or the pendulum mill. The bugbear of clinker rings and their disastrous effect upon continuity of kiln operation is also related to coal quality and fineness, and needs to be considered in connection therewith.

The type of brick for rotary kiln lining is a problem of recent origin. In England the ordinary English firebrick was the only one available until a few years ago, when the foreign brick containing over 60 per cent. of alumina was imported. The works manager now has to decide whether these high-priced aluminous bricks are worth while. Does it pay to use a common firebrick with a life of four months rather than an aluminous brick at three times the price and with a prospect of a much longer life?

For the utmost economy a rotary kiln must run continuously and with the minimum coal consumption, but then the question arises whether the output per running hour should be increased to an extent involving additional fuel consumption per ton of clinker; and again whether a high running output necessarily connotes a high fuel consumption.

The three chief items of cost in cement manufacture are kiln fuel consumption, labour, and power. The present-day wage rates are usually so high that the desirability of installing labour-saving appliances on a cement works is a foregone conclusion. Means of transport of material constitute a large proportion of such appliances and the makers of various types of conveyors and elevators, mechanical and pneumatic, have a wealth of argument which frequently makes decision difficult.

With regard to power in cement factories, the present tendency is towards

complete electrification and the purchase of electricity. The absence of a power plant on a cement factory removes a burden from the manager's shoulders and reduces the capital expenditure per ton of annual output, but it involves rejection of the heat value of the gases leaving the rotary kilns which might be employed in steam generation for power purposes.

Discussion Desirable.

Sufficient has been written to indicate that although cement manufacture is simple in principle, comprising two processes of grinding and one of heating, the details of the operations have such diverse possibilities that there is scope for much discussion, and it is intended that opportunity should be given for such discussion by experts, and others with more limited experience, but with useful records to produce as evidence. We should be glad to publish useful contributions on these debatable points, and hope all concerned with the cement industry will take the opportunity afforded by the publication of "Cement and Cement Manufacture" to ventilate their views on manufacturing problems.

Portland Cement Export Trade.

At the invitation of Mr. P. M. Stewart, Chairman of the Associated Portland Cement Manufacturers, Ltd., and the British Portland Cement Manufacturers, Ltd., there was held last month in London at the offices of those companies, an informal conference of the leading European cement manufacturers who are directly interested in the cement export trade. Representatives of Belgium, Denmark, England, France, Germany, Norway, Sweden and Switzerland were present.

We understand the conference was unanimous in agreeing that some form of co-operation to deal with the problems of the export business from Europe, and other matters of common interest, was desirable. The proposal is to be at once considered further by certain of the manufacturers nominated at the conference, who, from their intimate knowledge of the manufacturing conditions throughout Europe, will examine the possibilities of joint action and make recommendations to their colleagues.

Notes from Abroad.

New Works in Holland.

It is reported that the N.V. Eerste Nederlandsche Cement Industrie has commenced manufacture. The sales office will be in Amsterdam. The Works capacity has been variously given as 200,000, 250,000 and 300,000 tons per annum.

Purchase of Hungarian Cement Factory.

It is stated that the Hungarian General Colliery Co. (Felsogallai Co.) and the United Brick and Cement Works Co. have jointly acquired the Buda Cement Factory from the Hungarian General Real Estate Bank at the purchase price of 2,500,000 pengoes (£89,000).

Australian Contracts.

We understand Cement Distributors Pty., Ltd. has contracted for the disposal of the whole of the output of the Goliath Portland Cement Co. They are reported to have secured the following contracts: One-third of the total requirements of the Melbourne and Metropolitan Board of Works for two years: One-third of the total requirements of the Melbourne City Council for two years; The total requirements of the Melbourne Harbour Trust, for wharf construction, for one year; One-half of the Sydney Civic Commission's annual contract.

Electrical Driving of Cement Plant.

In order that this country should maintain its pre-eminent position as the home of the best Portland cement, it has been necessary for unceasing attention to be paid to the scientific aspect of manufacture and to the development of highly specialised machinery. As a result British-made cement is second to none, and it is interesting to note that whether the wet or the dry process of manufacture is adopted electrical driving is extensively used, the individual driving of machines and perfect control of every operation which this method of driving ensures being of particular value to the industry.

Various reasons have led to the widespread adoption of electric driving; notable economies have resulted from installations utilising electric power, increased output for a given power consumption being obtained in consequence. Under normal conditions cement mills are kept in continuous production, operating 24 hours a day for seven days a week, although the preparation machinery may be in operation for a shorter time, and it is important that the shutting-down of any one machine shall not affect the remainder of the plant. This condition is fulfilled by the sub-divided drive possible with electric power, and at the same time a continuous record can be obtained of the amount of power used in each of the different sections of a mill. Thus an accurate check can be kept on the cost of manufacture and condition of the machinery. Most of the machines start under heavy overload, even up to 200 or 300 per cent., and some are liable to overloads when in operation. Electric motors run at very high efficiency during normal operation and yet can be obtained with a large margin of overload capacity which is drawn upon automatically at any time either at starting or when in operation.

With the exception of rotary kilns, the majority of the larger machines used in the manufacture of cement are of the constant-speed type, so that, as the electrical supply available is usually three-phase alternating current, induction motors form ideal driving units in most instances, but for some of the larger powers synchronous motors are often used.

The preliminary crushing of hard materials is generally effected with gyratory or jaw crushers driven through belting, and sometimes provided with a break-pin in the driving pulley as a protection against damage. Individual driving or group driving of three or four crushers with their attendant elevators and conveyors is usually adopted. The starting torque required is generally somewhat more than the full-load torque of the motor.

Ball mills take more than normal torque at starting, due to the high frictional effect and the weight of the steel balls, which will all be at the bottom of the cylinder when it is at rest. When in operation the screens may become temporarily clogged, so that as the material continues to feed into the mill it may gradually fill up and require more power to drive it. This overload, however, is not likely to exceed 25 per cent. and lasts only for a short time. These mills revolve at about 20 r.p.m., and are supplied with a countershaft geared to the drum. Belt-drive from the electric motor to the countershaft is generally adopted, though the motor may be coupled to the countershaft through enclosed gearing, or, in some instances, direct through a flexible coupling.

Tube mills are used to finish the product of the ball mills. The essential components are a steel cylinder lined with some special hard wear-resisting material, and about half-filled with flint-pebbles or cast-iron pellets. The cylinder is supported on trunnion bearings and is rotated at a comparatively slow speed. The material enters through a hollow trunnion, moves through the whole length of the mill body while it rotates, and is discharged at the opposite end of the mill in a very finely-pulverised condition. The driving power required does not vary greatly with the class of material, degree of fineness of the previous grinding, or the fineness to which it is ground in the tube mill, although these factors materially affect the rate of feed and consequently the output. Sometimes considerable variation in the power required and output of a given size of mill may be noted due to the quantity of pebbles in the mill, and as the pebbles

wear down the power required by the mill decreases. In some plants the power taken is used as an indication of the state of the pebbles, so that new pebbles can be added when necessary. In determining the size and type of motor careful consideration must be given to the starting-torque required, which may be about twice the full-load torque of the motor.

In order to obtain the best results with the rotary kiln the firing process

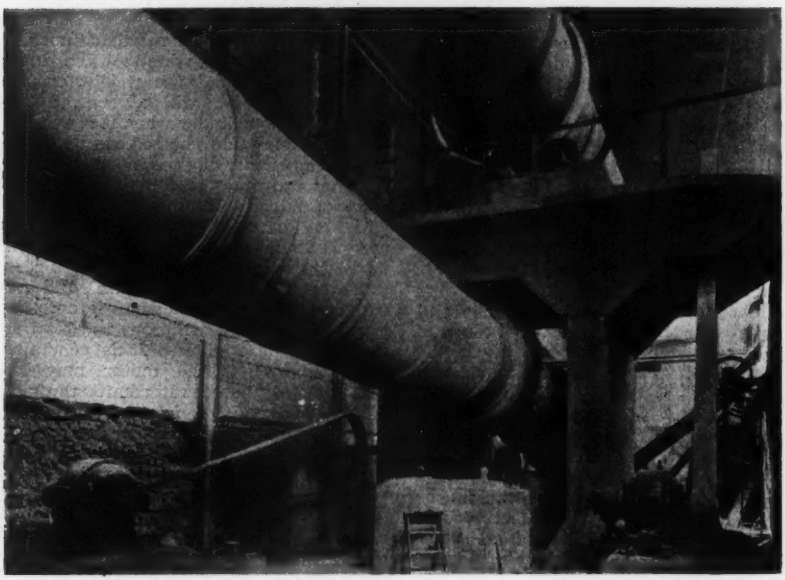


Fig. 1.—Induction Motors of 15 and 50 H.P. Driving Rotary Cooler and Rotary Kiln.

necessitates very careful control of the rate of feed of raw material, rate of feed of fuel, and speed of kiln. The raw-material feed and the coal feed should have a wide speed range with a very large number of intermediate speeds, and if a direct-current supply is available a D.C. variable speed motor may be used for this duty, while on A.C. the variable-speed A.C. commutator motor is suitable. A speed range of 3 to 1 is normal with motors of this type, brush-shifting control giving an infinite number of intermediate speeds. Thus the motors meet the requirements for feeding the pulverised coal and slurry to the kilns, and as the brush-shifting arrangement is easily adapted to remote control, a sensitive control of slurry and coal feeds can be obtained from the firing platform.

In addition to variation in the rate of feed of material it has been general practice to demand also speed variation of the kiln from maximum down to 75 per cent., or in some cases 50 per cent., of maximum. The speed control is obtained either by retention of the older line-shafting with speed-changing gears giving two or three speeds, or with cone pulleys giving a range of two or three to one (the driving motor being of a constant-speed type), or by using a variable-speed motor for each kiln. The drive may be taken from the motor through the medium either of belt or gearing, but, as the questions of ventilation and room temperature are important, belt drive is usually adopted, an incidental advantage

Fig. 2.—Induction Motor of 22 H.P. Driving Crusher and Elevator.

being that the motor is thereby removed farther away from the hot kiln.

If variable-speed A.C. motors are used, these may be either of the induction type with wound rotors or of the commutator type, but for a speed variation of between 25 and 50 per cent., which is ample in most cases, induction motors have proved quite satisfactory. The speed variation is obtained by means of adjustable resistance connected across the slip-rings, and, although the method does not give the highest electrical efficiency, no serious objection can be taken as the kiln drives

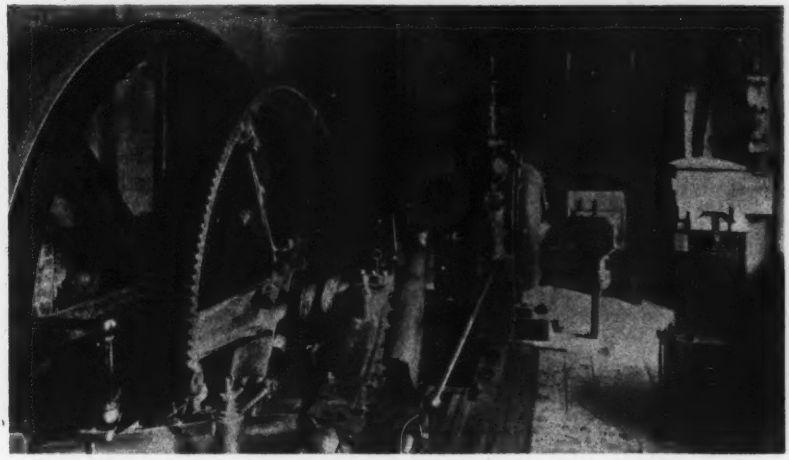


Fig. 3.—Engine Room at a Cement Works, showing Induction Motor of 175 H.P. taking the place of Steam Engine.

account for only a small percentage of the total power requirements in a cement works. It should be mentioned that by adding resistance to the secondary circuit the speed change for a given change in load is increased, and the greater the resistance the greater is the speed change, so that when operating at low speeds, changes in torque have a noticeable effect on the speed of the kiln. These changes may be gradual, as when due to such causes as the partial blocking of the kiln by the formation of a clinker ring, or they may occur every revolution due, for example, to the kiln being unbalanced.

In addition to synchronous motors, squirrel-cage and slip-ring induction motors, as mentioned above, synchronous induction motors, "No-Lag" power factor correction motors, and A.C. variable-speed commutator motors manufactured by the British Thomson-Houston Co., Ltd., are extensively used in the cement manufacturing industry, and in the following notes we describe some representative installations. "No-Lag" motors are started and stopped in exactly the same manner as ordinary slip-ring induction motors, but run at or above unity power factor so as to improve the power factor of the A.C. system to which they are connected. The effect of improving the power factor is that more useful power can be generated with the same generating plant at the power station than if only ordinary induction motors are connected to the supply system; as a result, the user obtains more advantageous terms for power, not only for that taken by the "No-Lag" motors but for all power taken from the system. Motors of this type have similar speed torque characteristics to those of ordinary slip-ring induction motors, and can therefore be used for any duty where slip-ring motors are suitable, whereas synchronous motors have a more limited field of application. In some cases a higher speed than the synchronous speed of the equivalent slip-ring induction motor may be required, and this can be

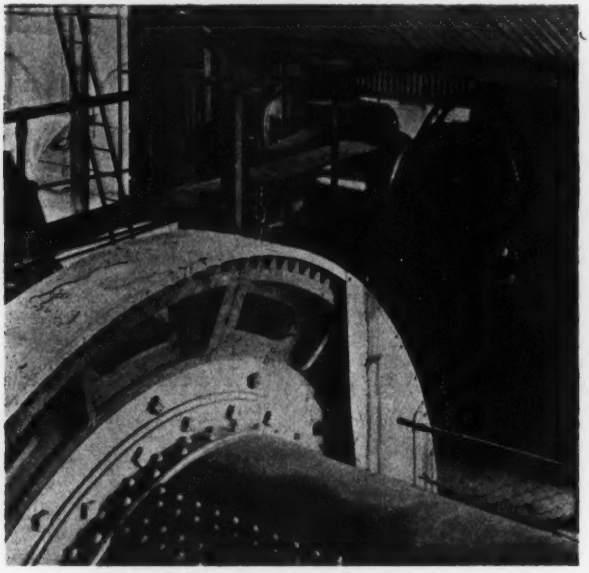


Fig. 4.—"No-Lag" Motor of 250 H.P. driving a Tube Mill; in background to left Induction Motor of 100 H.P. Driving Conveying Plant.

obtained if a "No-Lag" motor is used, as, when being designed, this special speed can be arranged for. As an example reference may be made to motors of this type driving bag-filling machines at works of the Associated Portland Cement Manufacturers, Ltd.

Variable-speed A.C. commutator motors are applied to various other drives than those previously mentioned, including the driving of coal screws for feeding pulverised coal to kilns, silo emptiers, slurry elevators, etc.

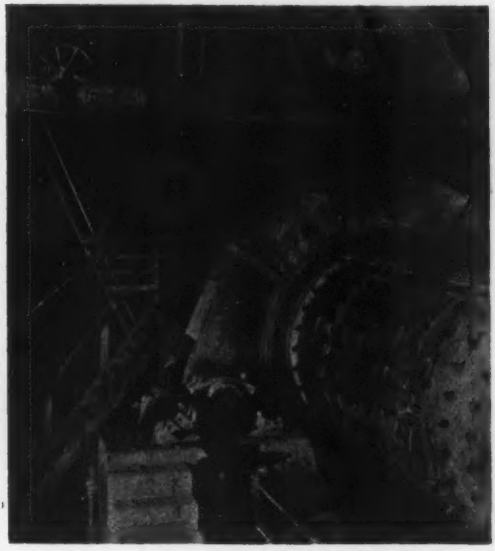


Fig. 5.—Tube Mill driven by Synchronous Induction Motor of 600 H.P.

Fig. 1 gives a view in the works of Messrs. Greaves, Bull & Lakin, Ltd. The electric motor on the left is driving a rotary cooler and the motor on the right a rotary kiln. The first mentioned is rated at 15 H.P. and the second at 50 H.P. Both are of the slip-ring type, the supply being at 433 volts, three-phase, 50 cycles. In *Fig.* 2 is seen another example of electrical driving in the same works; the squirrel-cage induction motor is of 22 H.P. and drives a crusher and elevator.

An illustration of the ease of converting from steam-engine to electric-motor drive is given in *Fig.* 3. Here is seen part of the original engine-room of Messrs. John Ellis & Sons, Ltd., at Barrow, near Loughborough, with a protected-type slip-ring induction motor of 175 H.P. installed to drive some of the original line shafting of the mills through "Fabroil" silent pinion gearing. The motor-control gear is also shown, the motor speed being adjustable by the use of resistance in the rotor circuit through the medium of a controller of the tramway type. Connected to the shafting are two 3-roll grinding mills, brick presses, elevators, and conveyors. The illustration shows a stage in the conversion, the policy pursued by Messrs. Ellis having been to adopt electric motors for all extensions, retaining the steam engine (which was built in 1883) in service until fairly recently. When it was decided to put the engine out of commission it was simply disconnected from the shafting and the motor installed during a week-end so as not to interfere with production. Since that date a new 3-chamber tube mill has been installed and the 175 H.P. motor transferred to another part of the works to drive this

mill, further re-arrangements having been made by the addition of other motors so that at the present time the drives throughout are on the individual or small group system. The electrical supply is 440 volts, three-phase, 50 cycles.

Another interesting electrical installation to which reference may be made is that at the works of the Rugby Portland Cement Co., Ltd. Here also the plant is now electrically driven, the motors being fed at 433 volts, three-phase, 50 cycles. The motors range from 2½ H.P. to 250 H.P., three of the larger size being of the "No-Lag" type. In *Fig.* 4 are seen a 250 H.P. "No-Lag" motor driving a tube mill and a 100 H.P. protected-type slip-ring induction motor driving conveying plant. One of the other 250 H.P. "No-Lag" motors drives two clinker ball mills, and another drives a crusher, tube mill, and elevator.

An example of a synchronous induction motor in a cement works is seen in *Fig.* 5, which shows a 600 H.P., 710 KVA ·7 leading power factor, 250 r.p.m., 440 volts, three-phase, 50-cycle machine driving a tube mill in the works of the Holborough Cement Co., Ltd. This motor is shown in greater detail in *Fig.* 6, which also gives a view of the starting cubicle and liquid starter.

In conclusion a word should be said about excavating equipment. Electrically-operated navvies are becoming increasingly popular for surface mining operations, their efficiency and usefulness being firmly established. In a plant which works continuously the ability of the electric excavator to work 24 hours a day is of great value, and, since there is no necessity to provide for transporting coal to the navvy, the wagon service can be organised for maximum efficiency. In addition to the elimination of coal handling, the cost and difficulties of supplying feed-water are non-existent, and no delays are experienced through freezing in winter. Electrical operation avoids such items as washing-out the boiler and lubricating the engines, while the time and money which would be spent in the

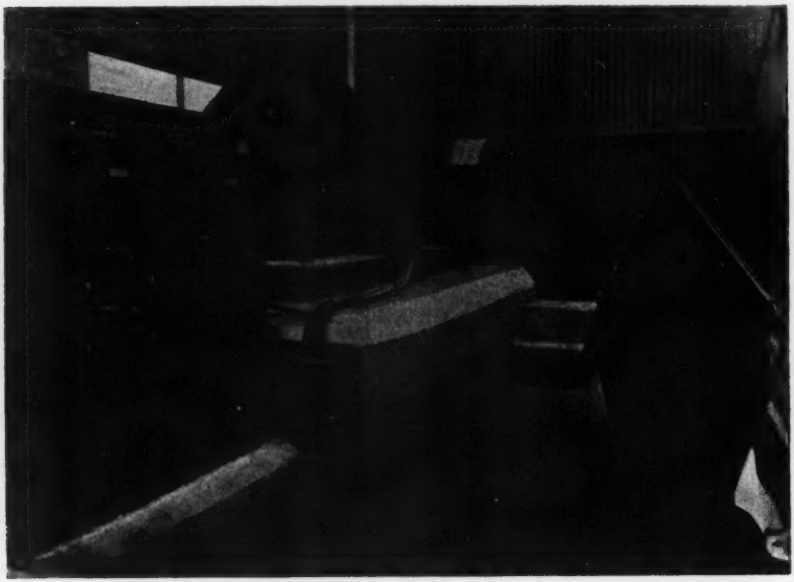


Fig. 6.—Synchronous Induction Motor of 600 H.P. driving a Tube Mill. Starting equipment also shown.

Fig. 7.—Electrically-driven Navvy in Chalk Quarry.

maintenance of the boiler and engines are saved and production is not held up for repairs of this nature. Electric navvies have the advantage of consuming power only when they are doing useful work, and also they can be set to work at a moment's notice after a shut-down. They are arranged for one-man operation, even the bucket latch being tripped electrically, if desired.

Electrical excavators are made in all sizes, with rail wheels or caterpillar tracks, although the latter form of mounting is rapidly becoming universal in quarries, as it shares with electrical operation the feature of reducing subsidiary labour to a minimum. In fact the electrical excavator on caterpillar tracks approaches very closely the ideal of a single-operator independent unit, needing the minimum of external assistance or service. A fairly large machine with complete electrical equipment is shown in *Fig.* 7 digging chalk at the Bevans Works (Northfleet) of the Associated Portland Cement Manufacturers, Ltd.

Wilson's (N.Z.) Portland Cement, Ltd.

THIS Company has again declared a 10 per cent. dividend. The Company's results for the past three years are as follows:

	1925–26.	1926–27.	1927–28.
	£	£	£
Brought forward	52,801	54,212	57,421
Net profits	86,411	88,208	88,245
	£139,212	£142,421	£145,666
Dividends, 10 per cent.	60,000	60,000	60,000
To reserve	25,000	25,000	25,000
Carried forward	£54,212	£57,421	£60,666

Modern Cement and Modern Cement Testing.

MR. D. B. BUTLER, A.M.Inst.C.E., F.C.S., writes as follows:

Referring to the criticism in your October issue of my recent article on "Modern Cement and Modern Cement Testing," may I be allowed to make the following remarks?

Overburning of Cement.

Your correspondent suggests that my remark as to overburnt clinker being altogether "spoilt and useless" is a fallacy. In the first place, I was merely comparing the different methods of manufacture of the two materials, i.e. Portland cement and aluminous cement, and although there may be something in your correspondent's criticism, the result from an ordinary manufacturer's point of view fully bears out my contention. The time may arrive, as was once suggested by the late Mr. Bertram Blount, when Portland cement will be manufactured by absolutely fusing the raw materials, but that time still appears to be far distant.

False Setting Times.

The whole question here is the proper protection of the user against loss of plasticity and workability of the concrete before manipulation is completed and the mass at rest in its allotted position. If practical and conclusive evidence is available that cement with quick initial and also quick final setting properties under two minutes' expert gauging does not lose its plasticity under working conditions, I will willingly withdraw my remarks on this point. With machine-made concrete the mixture is frequently discharged after considerably less than four or five minutes' mixing, and, further, it must not be forgotten that intensive trowelling for two minutes on the gauging slab is quite different from the mere turning over of the mass in the concrete mixing machine. Your correspondent, however, is scarcely correct in saying that in the instance I gave the initial setting time would necessarily be disturbed in moulding the briquettes and cubes. The sample in question having an initial set of seven minutes, allows that period for the moulding operation, and not two minutes, as your correspondent suggests.

Cement Fineness.

Your correspondent here suggests that the manufacturer should be allowed a free hand to do as he pleases, so long as the desired results are obtained. If that position is to be accepted, many of the specified tests now in force are superfluous. I must confess, however, that I cannot follow his argument as to the undesirability, until finality in strength is reached, of a Standard Specification for Rapid-Hardening Portland Cement. If finality is to be awaited before any specification is issued, why was the first British Standard Specification for ordinary Portland Cement issued some fourteen years ago? Judging from the present-day product, finality was far from being reached at that time. Since rapid-hardening Portland cement has now been on the market for the past three or four years, and its consumption is increasing enormously every year, it seems highly desirable from the user's point of view that its properties should be clearly defined in a Standard Specification. As with Portland cement, this Standard Specification could be revised from time to time as might be found desirable with future developments.

The Largest European Cement Works.

BEVANS WORKS, NORTHFLEET.

(Concluded.)

Powdered-Coal Hoppers. — Adjacent to, and forming one side of, the coal mill is the powdered-coal store shown in *Fig.* 2. This hopper is 64 ft. by 20 ft. by 39 ft. high to the top deck, which carries the feeding conveyors. The net capacity of the hopper is about 400 tons of powdered coal, and, as in the case of the dry coal hopper, a partition wall is provided so that half may be emptied if required without interrupting the working of the other half. The hopper is peg-top shape in cross section, but flat bottomed in longitudinal section in order to avoid expensive shuttering, the corners being dry filled and covered with concrete.

Slurry Mixers.—These are plain circular tanks of reinforced concrete, 66 ft. diameter, capacity 1,500 tons.

Fig. 1.—The Conveyor.

Elevator Casings.—An interesting feature of the coal and cement-handling plant is that the elevator casings (*Fig.* 3) are of reinforced concrete. This is a

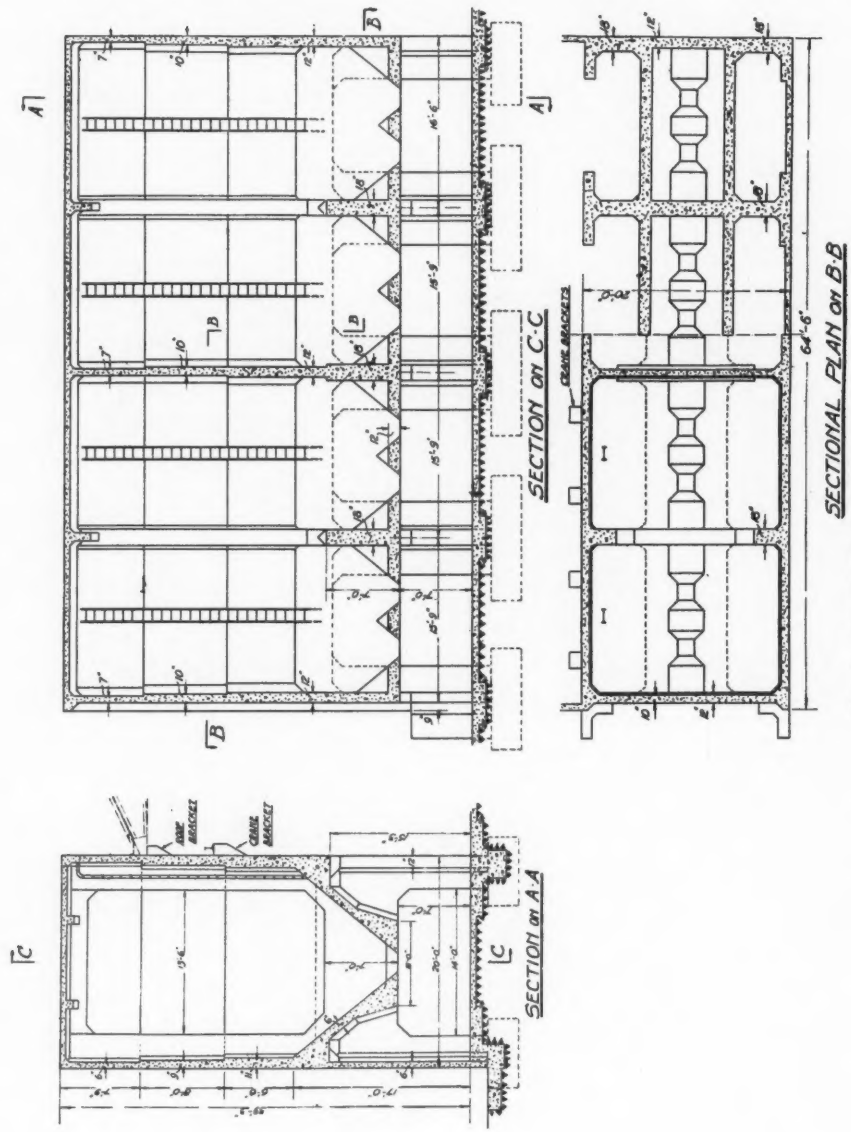


Fig. 2.—Powdered Coal Hopper.

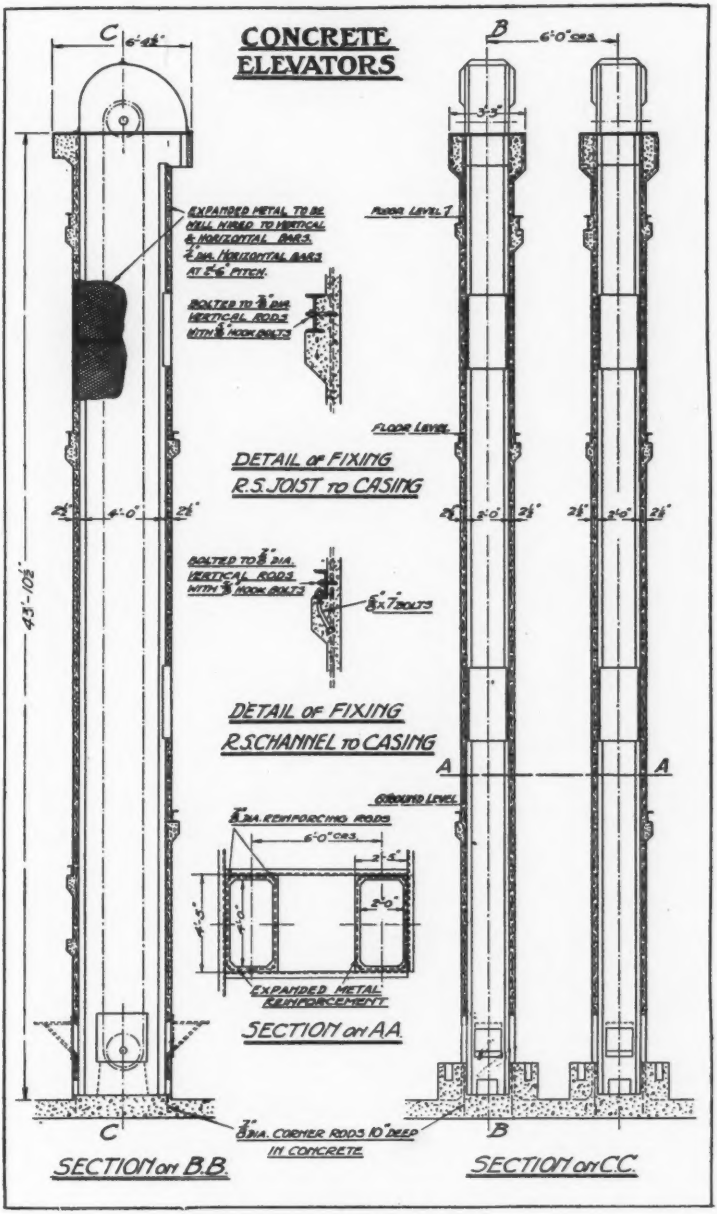


Fig. 3.—Concrete Elevator Casings.

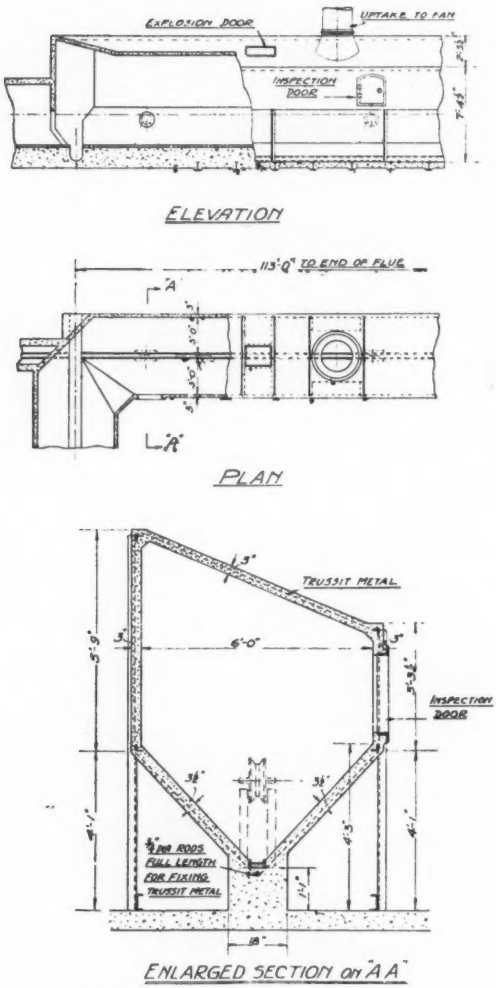
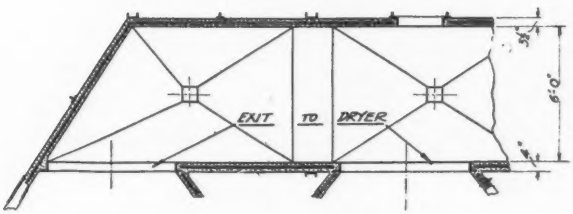
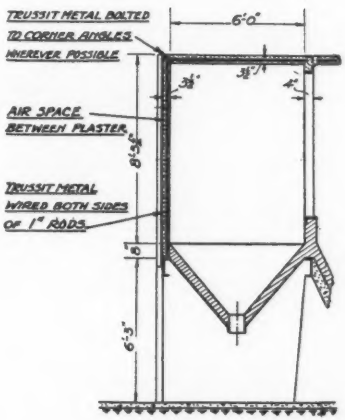


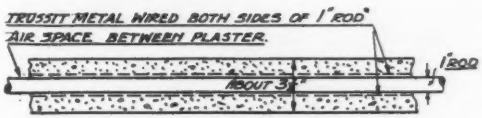
Fig. 4.—Hot Air Flues in Concrete.



SECTIONAL PLAN


TRUSSIT METAL BOLTED TO CORNER ANGLES WHEREVER POSSIBLE
6'-0"
AIR SPACE BETWEEN PLASTER
TRUSSIT METAL WIRED BOTH SIDES OF 1" RODS
6'-3"

CROSS SECTION



SECTION THRO' PLASTER SIDES AND ROOF.

Fig. 5.—Hot Air Flues in Concrete.

particularly useful arrangement for coal handling, as it is found that steel casings only last two or three years under the combined corrosive action of moisture and sulphur in the coal.

These casings are in some cases 60 ft. high, and are made of 2½-in. thick concrete, reinforced with expanded metal with one ⅞-in. diameter rod in each corner. Cast-iron door frames are built in to give access to the gear.

Hot-Air Flues.—In various other plants of the Company the brick-built hot-air flues to and from the coal dryer have given considerable trouble with air leaks through cracks caused by temperature expansion, and even when made of reinforced concrete there was not much improvement with any reasonable reinforcement.

In the flues at Bevans an attempt has been made to overcome these difficulties by hollow wall reinforced concrete construction, and so far this has proved quite successful. The temperature to be handled is about 400 deg. Fahr., but may go up to 600 deg. Fahr.

The design is shown on *Fig.* 4 from which it will be seen that the walls consist of two plastered slabs 1½ in. thick with an air space between. The framework is made up of angle or tee bar, to which are clipped 1-in. diameter mild steel bars at about 2 ft. 6 in. pitch, and on both sides of these bars "Trussit" is wired and plastered. The effect of this is to leave an air space equal to the diameter of the round bar between the two plastered slabs.

The plaster on the inside or hot side of the flue was composed of 1 part of Portland cement to 1 of ground firebricks, and on the outside 1 part of Portland cement to 2 parts of sand. The theory of the construction is that the inside plaster takes the brunt of the heat, and probably cracks, but the outside plaster and main framing remain comparatively cool.

Another type of flue to handle gases the temperature of which does not go above 300 deg. Fahr. is shown at *Fig.* 5. In this case a light angle framework supports a similar metal lath, which is plastered on both sides to a total thickness of 2½ in. or 3 in. with sand-and-cement mortar, about 2 to 1.

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Early Development of Portland Cement Manufacture.

By A. C. DAVIS, M.I.Mech.E., M.Inst.C.E.I., F.C.S.

In 1850 there existed in England about four large cement-producing factories, situated at Swanscombe and Northfleet in Kent, Wakefield, and Gateshead. The development of manufacture was first hindered by irregularity both in quality and output, and by the competition of the so-called Roman cement. It was only during the second decade after its introduction that improvements in the manufacture of Portland cement, brought about by an increasing knowledge of the chemistry of the subject, were beginning to bring this material more into favour with engineers, to the gradual displacement of Roman cement, although the latter, being particularly suitable for some purposes, continued to be manufactured to a certain extent.

In France, Portland cement first began to be used towards 1850. "First of all received with mistrust on account of its chemical composition, which classed it amongst the high lime so dreaded by builders," says M. Durand Claye, "it soon received notice on account of its special qualities, particularly in maritime work, for which exclusive privileges had been obtained for the Channel and the ocean coast." A factory at Boulogne-sur-Mer, originally engaged in the manufacture of other cements, was then used exclusively by the proprietor (M. Dupont) for the preparation of Portland cement, the regularity and excellence of the supplies being good propaganda for the material. In fact it was towards 1850 that MM. Dupont and Demarle began to deliver fairly large quantities of Portland cement; their first experiments date from 1846, but regular manufacture was only effected about 1848–50. M. Demarle found means of utilising the marly chalk beds discovered by Vicat, which to this day maintain the factory at Boulogne-sur-Mer. He was able, within a relatively short space of time, to improve manufacture as regards the treatment of raw material, and particularly the proportions to be used, and bring it to such perfection that his methods were followed.

The manufacture of Portland cement was still carried on in a very crude manner, but further experience and improvements in machinery and appliances and a gradual realisation of the fact that the manufacture of cement is essentially a chemical process, were bringing about a steady and increasingly rapid growth of the industry.

At the Great Exhibition held in Hyde Park in 1851 tests were made with "briquettes" of cement, and the breaking strain of neat Portland cement was 414 lbs. per sq. in. at three months. There is still preserved at White's factory at Swanscombe a large block of concrete, made with their Portland cement, which was exhibited at this Exhibition. The Exhibition undoubtedly gave a great impetus to the industry, and it is interesting to note that in 1859 Mr. John Grant, Engineer to the Metropolitan Board of Works, decided to use Portland cement in the construction of the London Drainage Canal, and published his reasons at the time for so doing in the *Transactions* of the Institution of Civil Engineers. This decision no doubt also helped to bring the new cement to the front.

Other factories began to spring up—the presence of ample supplies of chalk and the excellent alluvial clay of the Medway (materials which were found to be

unsurpassed for the manufacture of Portland cement) offering strong inducements to manufacturers, and these districts have become known as the "cradle of the industry." The first works on the Medway was established at Frindsbury, near Rochester, followed by others at Upnor, Halling, etc. The number of factories on the Thames also became rapidly augmented, and met with more or less success.

In the early Portland cement manufacturing days science and progress were evidently extremely slow and differed vastly from the pace of modern times, since it took nearly thirty years—from 1824 to 1852—to improve upon the manufacture as known to Aspdin up to the standard of quality manufactured by G. F. White, who stated in his paper before the Institution of Civil Engineers in 1852 that "in seven days Portland cement attains a cohesive power of more than 100 lbs. per square inch." This is not nearly the strength which is obtainable from the ground hydraulic limes of to-day, and therefore the Portland cement of 1852 was even inferior to modern hydraulic limes; this gives some idea of the degree of burning cement at that date. Such cement was even then, however, called "most highly calcined," and to this cause must be referred the excellence of the artificially-produced Portland cement known at that time.

G. F. White's paper concerning the quality of Portland cement marketed in this period is an enlightening record of the early days of the use of Portland cement in preference to Roman cement. It is entitled "Observations on artificial hydraulic, or Portland, cement; with an account of the testing of the brick beam erected at the Great Exhibition, Hyde Park," and is quoted at length in the author's book "A Hundred Years of Portland Cement."

It is shown in this paper that since 1838, when descriptions were given of tests in the bonding of bricks, etc., considerable improvements had been made in the manufacture and uses of cement, the most remarkable being the introduction of "the Artificial substance called Portland Cement."

The adoption of these artificially-compounded materials in preference to those made from natural cement stones had for some time been gaining ground. The chief application, however, was in connection with bricks, which could be adjusted in position before the cement began to set, even though used pure. The properties, however, which rendered cement valuable as a connecting medium in brickwork operated unfavourably to its use in masonry, since with all the care that could be taken waste from rapid setting would ensue, and to avoid the loss consequent on such waste it was very common to re-work the cement, thereby interfering with the setting process. Prejudice in France against quick-setting cements made from natural stones had led to the extensive use of the hydraulic limes, with an admixture only of sand, pozzolano, trass or artificial pozzolanos made of calcined clays.

Though successful in some cases it was notorious that in the majority of instances where the artificial pozzolanos had been used on a large scale failure had followed. M. Vicat examined closely the causes of these failures and concluded that the hydrochloride of magnesia in the sea-water penetrated the imperfectly carbonated portion of the cement and led to disintegration. He was thus led to believe that pozzolanos produced by volcanic heat differed from those produced artificially, and the inference would be that to create a perfect cement it was necessary to mix the clay with the carbonate before calcination.

Contemporaneous with these researches in France were those of Frost in

this country, but, as he did not apply to his mixture the needful calcination, Frost's cement did not attain the strength of Roman, nor did it dislodge that material from public esteem.

General Pasley appeared to have shared the opinion of Frost that artificial cements would supersede natural cements, and tried many experiments on the proportions in which carbonates and clays should be blended. The problem to be solved was that of producing, by judicious combination of carbonate of lime and alumina, a cement superior to those resulting from the calcination of natural stones.

This desideratum had apparently been attained in Portland cement, a material combining the characteristics of the best cements with the properties of limes. This two-fold property was almost peculiar to Portland cement and not shared by those made from natural stones. Ordinary Roman cement was rarely mixed with a larger quantity than two volumes of sand to one of cement; it was not used for concrete, and when employed as grout its setting properties were so much injured as to leave it questionable whether it added to the solidity of the construction. On the other hand, four, five, or six parts of sand might be mixed with Portland cement to form mortar, the proportion, less or more, being a question of time afforded for setting and not one of deterioration of quality from excess of foreign matter.

According to White, in making Portland cement in 1852 chalk and clay mixed in definite proportions were carefully ground together in water, and the mixture then run off into backs or reservoirs. After attaining a specific consistency it was artificially dried and removed to the kiln, for calcination to a much greater extent than that needed for lime and Roman cement. It was next delivered to the mill for grinding, and after being sifted it was packed for use, the important points of uniformity in colour and time of setting having been ascertained by experiments. Daily trials of the strength of the cement were made by moulding it into bricks, which twenty-four hours after setting were exposed to rupture by extension. The increase in strength was considered remarkable. In seven days it attained more than 100 lbs. per sq. in., and at the end of three months a strength equivalent to 414 lbs. per sq. in. To the variety of processes, to the extra fuel employed, and to the time and care expended upon the manufacture the cost of Portland cement was attributed by White.

M. Vicat had made some observations on what he called *ciments grules*, in which he mentioned Portland cement. He said setting was variable from an hour to weeks, and the difficulty of grinding and the quantity of fuel required were in his judgment insuperable obstacles to their adoption, but he stated that if their property of progressive hardening and cohesive powers be examined they would be found quite remarkable and greatly in excess of the best natural hydraulic limes—200 lbs. per sq. in. being the greatest resistance to compression obtainable by limes, while the highly-calcined cements acquired that hardness in a few days and reached 700 lbs. per sq. in., a resistance superior to that of calcareous lithographic limestones. Two volumes of sand reduced this resistance to about 350 lbs. per sq. in., or one-half; but it was true that these cements resolved the problem of producing an artificial stone equal in hardness and density to compact limestones.

G. F. White mentioned that the eventual resistance to compression of Portland cement then was: When used pure, 2,000 lbs. per sq. in.; with two volumes of

sand, 1,250 lbs.; and as a concrete stone, about 1,750 lbs. (N.B.—In 1928 the compression strength of Portland cement concrete made with 4 parts of ballast, 2 parts of sand, and 1 part of cement reaches 4,750 lbs. per sq. in. when 7 days old.)

According to Vicat the most noticeable fact in these cements was their great hardness and the resistance they consequently offered to the combined action of the sea and shingle in the most exposed situations, agencies which very speedily destroyed the pozzolanic mixtures and the best hydraulic limes.

At that time the agency to which cements owe their power of setting and consequent induration was not well understood. It was commonly considered that this was due to absorption of carbonic acid gas from the atmosphere, but G. F. White stated that about that time it was ascertained by chemists that it was the chemical union of the lime with silica and clay, and the consequent formation of a double silicate of lime and alumina, that produced the effect. The peculiar affinity of the lime to the alumina and silica appeared to be exerted most powerfully with those cements, whether natural or artificial, which were most highly calcined and consequently set the slowest, and to this cause he referred the excellence of the artificially-produced Portland cement. The large proportion of sand and gravel that could be mixed with Portland cement without materially affecting its cohesive power gave it an immense advantage over lime.

It is of interest to note also that G. F. White records experiments made on the adhesion both of Portland and Roman cements to various stones. The average of these trials showed that a force of 5,276 lbs. was required to tear asunder two 6-in. blocks of Portland stone joined with Portland cement, or 146 lbs. per sq. in. of sectional area; while with granite the resistance was but 97 lbs., 76 lbs., and 57 lbs. respectively per sq. in. The joint between the cubes of stone was barely one-eighth of an inch in thickness, and the stone was broken before the separation of the joints could be effected. The results further showed that the connecting power of Portland cement compared with Roman cement was as 3½ to 1.

The following is a résumé of the trials by compression made on blocks 9 in. square and 18 in. long, the pressure being exerted on the end of the blocks.

	Tons per sq. ft.
Roman cement and two parts sand bore	5·33
Portland cement and three parts sand bore	44·00
Roman cement, pure, bore	50·00
Portland cement and two parts sand bore	80·00
Portland cement, pure, bore	146·00

Experiments on cross-strain at the Great Exhibition of 1851 were made on beams of pure cement supported at both ends and loaded in the centre, 4 in. in depth by 4 in. thick with a clear bearing of 16 in., and gave the following results:—

	Lbs. per sq. in.
Portland cement, pure	99
Portland stone	80
Sheppey cement	61
Harwich cement	24

In the discussion on White's paper General Pasley said his object had been to produce a cement resembling what was called Roman cement and congratulated himself that his endeavours had led to the introduction of a cheaper and better

quality. G. F. White's practice surprised him in one respect, namely, that a strong cement should bear a greater proportion of sand than lime, nor could he understand the statement in the paper that, in order to make good concrete, cement should set slowly. The largest masses of masonry might be put together either by artificial or natural cement, and had Smeaton been aware of this fact it would have saved him the trouble of dovetailing the stones in the construction of the Eddystone Lighthouse.

Another speaker (Mr. Gravatt) expressed the opinion that the real test of the strength of a cement was to attach the bricks together one under the other and suspend the whole perpendicularly, and mentioned that during the construction of the Thames Tunnel sometimes as many as four hundred experiments were made in a week, every cask being tested. The brickwork was built in equal parts of Roman cement and sand. It was perfectly hard at the end of a week; after six months it became much softer, but at the end of a year it recovered its former hardness. The middle pier was first constructed solid and the side arches were cut through after an interval of about six months, as it would have been very difficult to have done so either before or afterwards.

In reply, G. F. White said the cements made by Pasley or Frost were not identical with the material then known as Portland cement. The constituents of the three cements were, however, similar, and they differed but little in the proportions employed; but both Pasley and Frost stopped short at the all-important point of calcination and they rejected that part of the kiln as overburnt which was found to yield the most valuable product. The aim of Pasley had been to rival the natural cement, and he had succeeded; but it had been reserved for another operator to produce in Portland cement a material which should far outstrip in cohesive power any of the natural cements known in this country.

Some interesting results of tests of cements made some years after those quoted by White in his paper, i.e. in 1864 and 1865, are given below.

Medina (Roman) Cement Tests in 1864.

Results of experiments with Medina cement, manufactured by Francis Brothers, in 1864. (Sectional area, 2·25 square inches. Original mould.)

Time kept immersed in water.	Neat Cement.		
	Minimum Breaking Test. Per sq. in.	Maximum Breaking Test. Per sq. in.	Average Breaking Test. Per sq. in.
	lbs.	lbs.	lbs.
7 days	37	44	41
,, (2nd series)	87	104	94
14 days	106	150	135
21 ,,	122	148	132
1 month	94	154	136
3 months	187	208	199
6 ,,	167	195	183
9 ,,	195	225	203
12 ,,	203	234	212
2 years	104	146	123
3 ,,	89	152	127
4 ,,	104	191	128
5 ,,	109	176	136
6 ,,	137	211	162
7 ,,	150	195	168

Roman Cement Tests in 1865.

Results of experiments with Roman cement manufactured by J. B. White and Brothers in 1865. (Sectional area 2·25 square inches. Original mould.)

Time kept immersed in water.	Neat Cement.		
	Minimum Breaking Test. Per sq. in.	Maximum Breaking Test. Per sq. in.	Average Breaking Test. Per sq. in.
	lbs.	lbs.	lbs.
7 days	76	106	90
14 ,,	71	84	77
21 ,,	76	91	83
1 month	109	129	116
3 months	136	153	143
6 ,,	196	223	210
9 ,,	139	231	209
12 ,,	265	302	286
2 years	212	271	243
3 ,,	232	288	268
4 ,,	267	292	281
5 ,,	259	294	279
6 ,,	268	316	296
7 ,,	287	347	315

Grant's Cement Tests in 1865.

Results of experiments with Portland cement weighing 123 lb. to the imperial bushel, mixed neat, with an equal proportion of clean Thames sand, showing the breaking weight on a sectional area of 2·25 sq. in. These form part of a series intended to extend over ten years. The whole of the specimens were kept in water from the time of being made till the time of testing.

Age.	Neat Cement.	1 of Cement to 1 of Sand.
	Average Breaking Test of 10 Experiments. Per sq. in.	Average Breaking Test of 10 Experiments. Per sq. in.
	lbs.	lbs.
7 days	363	157
1 month	416	201
3 months	469	243
6 ,,	523	285
9 ,,	542	308
12 ,,	547	318
2 years	589	351
3 ,,	584	349
4 ,,	584	364
5 ,,	580	365
6 ,,	581	364
7 ,,	590	384

The position of the Portland cement industry about the end of the second quarter of a century after its initiation is again well illustrated by a writer in 1874 (George R. Burnell), who described the cement materials in use at that time and also refers in interesting terms to the "new" Portland cement then introduced on to the market. In this article Burnell states that the experience of the best Continental engineers had led them to prefer the use of artificial hydraulic limes wherever natural ones were not to be met with.

There were two methods of preparing the artificial hydraulic limes. The first, the more perfect but at the same time the more expensive, consisted in mixing the slacked rich lime with a certain proportion of clay and burning this compound, the lime in this case going through a double calcination. The second method consisted in mixing, instead of the slacked lime, soft calcareous matters with the clays, such as chalk, or the tufas of some of the other formations, and in reducing the whole to a paste by grinding them together in a mill. Generally speaking, 20 parts of dry clay were mixed with 80 parts of very pure rich lime, or with 140 parts of carbonate of lime; but if the lime or the carbonate contained clay in their composition a smaller proportion was necessary.

Burnell records that at Meudon, near Paris, some extensive lime works were erected, under the direction of Vicat, by MM. Brian and St. Leger for the manufacture of artificial hydraulic limes from the chalk and clays of that country. The chalk was divided into pieces of the size of a fist previously to being ground. A large vertical mill with two horses crushed and mixed the materials with a plentiful supply of water, in the proportion of four parts of chalk to one of clay. The liquid was run into five troughs placed at successive differences of level, and deposited in them the matter it held in suspension. A double set of these troughs was necessary in order that one might be worked whilst the liquid was depositing in the other, and it was found that the shallower the troughs were in proportion to their surface the more rapidly did the deposition take place.

As soon as the deposited matter became of sufficient consistence to support manipulation it was made into small prisms with a mould. The prisms were then placed on a drying platform and allowed to dry until they arrived at the state of freshly-quarried limestone. They were then put into a kiln and burnt.

In England a somewhat similar process was followed in the manufacture of Portland cement. Burnell considered this nothing but an artificial hydraulic lime composed of the diluvial clay of the valleys of rivers, mixed in definite proportions with the chalk of the same geological districts. These materials were very finely comminuted under mills, and with water; they were allowed to deposit, and were then desiccated and burnt. But here began the difference, and the most delicate part of the manufacture. Instead of merely driving off the carbonic acid gas, calcination was taken to a point which produced vitrifaction in a very considerable portion of the contents of the kiln. The lime was, in fact, overburnt, and often irregularly so. Great care was therefore required in grinding the different products of the calcination to secure a proper equality in their times of setting; all the overburnt limes, like the natural cements, slacked with so much difficulty when in large masses as to require to be broken up before being used. There was also attached to the Portland cement the danger of occasionally expanding in setting. For this reason Burnell recommended that it should never be used unless in positions where this action, which the manufacturers did not appear to be able to control, would not be prejudicial to the work. When carefully prepared it was invaluable for external plastering, because it did not allow of the formation of vegetation like the natural cements; but unless great care had been taken in its manufacture it should not be used for large masses of masonry.

There was then a material manufactured in the Midland Counties sold in London under the name of Portland cement which Burnell recommended should

be used with even more caution than the material it was intended to represent. This was composed of ordinary blue lias lime, mixed in powder with definite proportions of clay obtained from the intercalated beds of the same geological formation, and burnt in close retorts. With this cement solidification did not take place with sufficient rapidity to allow of its being used under water in many cases where the real Portland cement would succeed.

The use of the then Portland cement advanced so slowly, however, that so late as 1874 Lieut.-Col. Sir Wm. Denison, Royal Engineers, wrote in his "Notes on Concrete" published in that year: "The very general employment of the mixture of lime and gravel, commonly known by the name of concrete in all foundations where, from the nature of the soil, precautions against partial settlements appear necessary, and the great probability of an extension of its use in situations where the materials of which it is composed are easily and cheaply procured, must of course render it a subject of great interest to the engineer."

As further illustrating the progress of the Portland cement industry in the United Kingdom, a few years later (1878) it is of interest to quote from a further article by Burnell:

"Portland cement as manufactured in the neighbourhood of London is made by a mixture of the chalk and clay of the alluvial formations of the lower parts of the Thames and Medway; the chalk being derived from the upper members of that formation, or from the chalk with flints, and the mud being principally derived from the deposition of the tidal waters. These ingredients are ground with a great quantity of water under edge rollers, and they escape through species of sieves in the requisite proportions, to flow off into large backs or reservoirs, where they part with a great proportion of the water used for their levigation. Of course there can be little certainty as to the proportions of the chalk and clay that are thus mixed, as they may both of them vary much in their chemical composition; but as a general rule the manufacturers endeavour to secure a mixture in which the carbonate of lime should be present in about the proportion of 60 per cent. of the whole mass, the silicate of alumina in the proportion of 34 per cent., and the rest would be composed of various ingredients that are found in the alluvial mud. After the mixture has been allowed to settle in the backs it is dug out in the plastic state and submitted to a species of desiccation; it is put into bottle kilns in the state of a hard paste, and is there subject to a great heat such as is capable of producing a pyrogenic compound of the silicate of alumina and lime. Great care is required in the management of the kilns in order to secure as nearly as possible an equal degree of calcination in all the materials that enter into the charge; but the principle that the manufacturers aim at in this operation is to give as much as possible a uniform degree of heat to every particle of the mixture, as they are thus enabled to calculate upon the setting qualities and the various physical conditions of the cements.

"There are three qualities that frequently characterise the products of a kiln—the under burnt, the properly burnt, and the over burnt; and it is upon the judicious mixture of these that the success of the operation of the burning must depend.

"The Portland cement is ground under millstones, placed so as to revolve horizontally, and it escapes from these stones through a sieve to be spread out on a floor where a species of cooling and of air-slacking is allowed to take place,

which is found to be very beneficial to the future stability of the works into the composition of which the cement enters. The specific gravity of the Portland cement ground in this manner may be taken at about 1·200, water being 1·000, and it is believed that this weight is a favourable condition; in fact, the consumers of Portland cement seek this quality of weight to such an extent that an ingenious system of fraud, which consists of mixing that article with the slag of the iron works, has lately been practised to a considerable extent.

"The cement, after being ground, is passed through a sieve that has 46 holes to the square inch, and is packed in casks which are kept carefully water-tight.

"The usual conditions of setting that are imposed by hydraulic engineers are that when gauged neat the cement shall set in the open air within the space of not less than two hours, so that it should be able to support the weight of a Vicat's needle loaded with the weight of $3\frac{1}{4}$ lbs.: the cement that sets in less time than the above is rejected in all cases where the engineers attach importance to the quality of this material."

These papers are quoted *in extenso* in the author's book "A Hundred Years of Portland Cement," and form an early historical record of the first official occasions when the subject of the quality of the then new Portland cement was openly written upon and discussed by independent critics. However, from this date onwards and during the last quarter of the nineteenth century, quality had improved and output had gone up in proportion with the result that a big industry was then built up at home for the supply of cement to most markets of the world.

(To be continued.)

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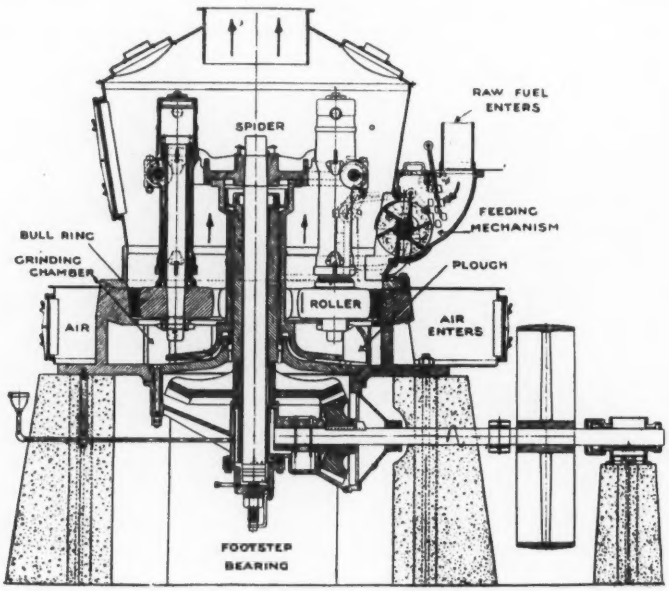
Pulverised Fuel.

In view of the interest to the cement and allied industries of pulverised fuel firing, it is interesting to note that to-day probably 75 per cent. of the coal consumed under steam boilers in the pulverised condition, probably 20,000,000 tons per annum, is burnt on the "Lopulco" system. The latest design of the plant has a much shorter over-all height of the setting; a new type of continuous, vertical, cylindrical, steam-heated rotary dryer with vertical scrapers (or alternatively drying by passing hot air through the "Raymond" pulverisers); an improved type of rotary feeder superseding the screw design; and a new short-flame turbulent type "R" burner. A dust separator is fitted at the chimney base through which the induced-draught fans discharge, while the pulverising equipment and bunkers are now generally placed at the back of the boilers instead of over the top to reduce the height still further.

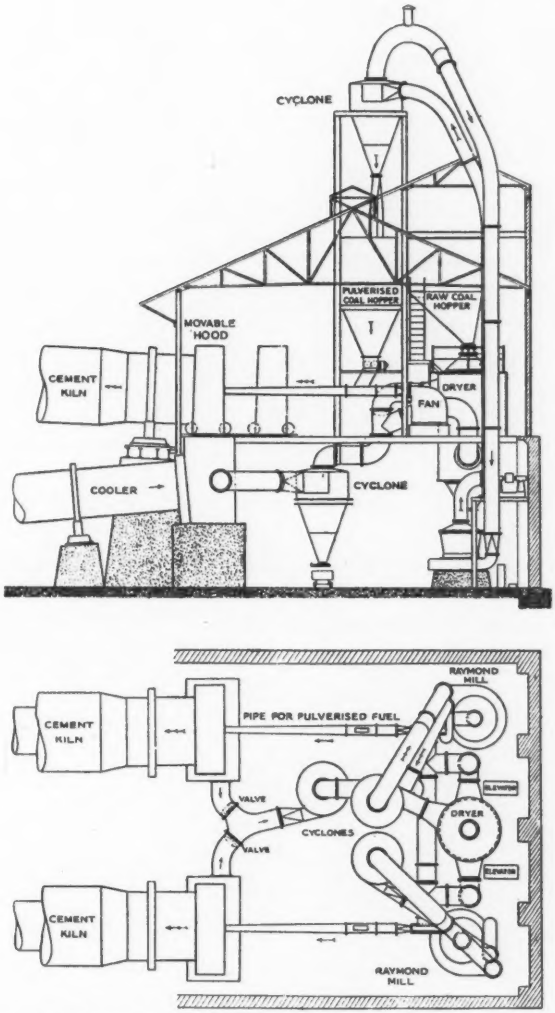
As usual, each boiler is entirely independent with its own pulveriser, cyclone, pulverised-fuel bin, feeder, "R" burner, air heater, dust separater and induced and forced draught fans, with separate control of adjustment of the pulveriser, feeder, and air supply for the burner. In a line of boilers the pulverisers and pulverised-coal bunkers are so interconnected for convenience or emergency that any individual boiler or number of boilers can be operated by different pulverisers. The new "R" burner will take up to 150,000,000 B.Th.U., or 6 tons of coal, per single unit, with air pressure not over 2 in. W.G. and control by a single damper.

The lay-out illustrated is a typical equipment for two rotary kilns, and consists of: Magnetic separater to remove tramp iron from the coal; dryer to reduce the moisture in the coal; two Raymond pulverisers with exhauster fans; two cyclones to remove coal from the carrying air; cyclone for separating dust from hot air of the clinker cooler.

The pulverised fuel passes from the



The "Raymond" Pulveriser.



Pulverised Fuel Equipment at a Cement Works. (*See p.* 84.)

cyclones to the storage bunkers, from which it is fed as required by special feed screws to the kiln firing pipe; there it meets a current of preheated air which carries it into the firing zone, where it burns in a flame about 30 ft. long. The motors required for the pulverisers and other machinery capable of dealing with 6 tons of fuel per hour are as follows: Two 10 H.P. for elevating and handling the raw coal; two 95 H.P. for pulverisers and exhauster fans; two 20 H.P. for fans for the combustion air; two 5 H.P. for screws to feed the pulverised coal. One six-roller Raymond pulveriser is sufficient to supply all the coal necessary to fire two rotary kilns, the second being a stand-by.

MODERN METHODS OF CONCRETE MAKING

IN this book, written by A. E. Wynn, B.Sc., A.M., Am.Soc. C.E., and Ewart S. Andrews, B.Sc., M.Inst.C.E., are described in simple and readily understood language the methods of making concrete at a minimum cost. The cement-water ratio is fully and simply explained, and tables and curves are given showing the quantity of water necessary to give maximum strength with different concrete mixes and with different size-aggregates. It is clearly shown how the use of the correct water content enables the cement content to be reduced, with consequent economy.

This new edition has been enlarged to include data relating to typical British Portland cements and rapid-hardening Portland cements. As the result of an extensive investigation and many tests by Mr. Ewart S. Andrews, curves have been plotted relating to these British cements, from which one can see at a glance the amount of water and cement necessary to produce concrete of any desired strength at 28 days or three months.

The authors point out that the strength of concrete is governed by water content more than by any other factor, and that by making use of the data and curves in this book it is now possible to design a mix that will not vary however much water is used providing the cement content is reduced or increased according to their rules.

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